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PRINCIPLES IN THE MANAGEMENT OF TRAUMATIC WOUNDS AND IN INFECTION CONTROL*

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INFECTION has always been an aspect of surgery that could not be ignored and remains so today. Infectious microorganisms are everywhere in man's environment and, given the opportunity, tend to invade the tissues of the body and to produce significant pathophysiologic effects on bodily functions. These microorganisms are remarkably adaptable to changes in circumstance, including new modes of treatment. If surgery is to be effective and wounds are to heal normally, such organisms must either be excluded from wounds or their growth must be adequately controlled. In effect, every surgical operation is an experiment in applied bacteriology.

The term "trauma" is understood to encompass both blunt and penetrating injuries to any part of the body. Such injuries result from violence,

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TABLE I. SHORT-TERM EFFECTS OF INFECTION REQUIRING TREATMENT

Increase in heart rate
Fever
Increase in respiratory rate
Decrease in blood pressure
Changes in volume of circulating blood
Alterations in cardiac function
Changes in the peripheral circulation
Impairment of renal function
Changes in blood composition and coagulation
Alterations in pulmonary function, with impairment of respiration and oxygen transfer
Derangements in lymphatic function
Depression of resistance and immunity
Alterations in central nervous system function
Alterations in endocrine function
Impairment of wound healing

accidents, or surgery. Trauma also may pertain to heat or cold injuries, animal or human bites, and stings of venomous snakes, insects, fishes, coelenterates, or echinoderms. The damage that results from trauma may be local, regional, systemic, or in combination.

SCOPE AND IMPORTANCE OF INFECTION IN TRAUMA

At the start of this decade trauma was the fourth leading cause of death in the United States,[1] and more recently it has been the chief cause of death among males between the ages of four and 40 years. It is noteworthy that there was a 400% increase in the number of patients with gunshot wounds of the abdomen admitted to the surgical service of Cincinnati General Hospital between 1967 and 1970.[2]

When injured patients become infected, the surgeon must be concerned about both short-term and long-term consequences. More than a dozen short-term effects of infection may require treatment (Table I).

Serious long-term consequences may affect morbidity or mortality; loss of bodily function may be prolonged or made permanent; and deformity, disfigurement, or loss of limb may occur. The very physical and psychological quality of the patient's life may be altered as the result of infection.

Economic consequences of infection for both hospital and patient include increased medical costs, prolongation of hospital stay and daily control costs, and temporary or permanent loss of income for the patient.

Although there are no accurate, up-to-date data on the overall incidence of post-trauma infection, it is estimated that approximately 7.4% of patients involved in 18.8 million surgical operations of all types in the United States in 1967 developed postoperative infections.[3] The separate rates in a collaborative study in five university hospitals for clean wounds, clean-contaminated wounds, and contaminated wounds were 5.1%, 10.8%, and 16.3%, respectively.

Unfortunately, in more than 35 years of modern antibiotic therapy, the overall incidence of infection among surgical patients has not decreased. Moreover, the incidence of infection among trauma patients is more likely to increase than decrease.

Despite the fact that wounds are almost invariably contaminated to some degree, infection does not always occur. Whether bacterial contaminants succeed in colonizing wounds and producing infections depends upon a number of factors. Prime among these is the physiological state of the tissues, subject to modification by several variables. Thus, the etiology of wound sepsis may be both microbial and nonmicrobial. The nonmicrobial factors are of great importance and worth further consideration.

Nonmicrobial Etiologic Determinants of Wound Infection

Devitalized tissue in the wound. Torn, devitalized muscle and other tissues are commonly found in wounds caused by violence (e.g., crushing injuries, extensive lacerations, gunshot or high-explosive wounds, burns, compound fractures, or fracture dislocations). Although healthy tissues are remarkably resistant to bacterial growth and infection, the presence of dead, irritated, or unhealthy tissue promotes colonization of bacteria in wounds and resultant infection.

Impaired local circulation. Another factor in wound infection is impairment of the local circulation. Thrombosis, damage to large vessels, displacement of fractures, improperly applied tourniquets, ill-placed casts, tight packing of wounds, or closure of wounds under tension can cause ischemia; local derangement in the physiologic state of a wound favors bacterial growth and invasion.

Wound location. Body sites differ in resistance to infection. Wounds of the face, scalp, or thorax are less susceptible to infection than wounds of the abdomen, thigh, calf, or buttock.[5,6] On the other hand, the chance that lacerations of the face and neck will become infected is increased if these wounds communicate with the mouth or pharynx.

Foreign bodies. Foreign bodies in wounds are locally irritating and often harbor masses of microorganisms. The virulence of contaminating clostridia may be increased by the presence of such foreign bodies as cinders, gravel, soil, fragments of metal, glass, or wood, or bits of clothing. In laboratory animals, Altemeier and Furste demonstrated that the minimal number of *Clostridium perfringens* needed as an inoculum to produce a fatal infection was one million times less when injected in the presence of crushed muscle and sterile dirt than when injected into normal healthy muscle.[4] Sutures embedded in tissues are foreign bodies, although necessary ones. When silk or cotton sutures are used aseptically and with gentle handling of tissues, healing with a low incidence of infection occurs in a high percentage of cases. They can also be used successfully within the peritoneal cavity, even in the presence of gross contamination or active infection. Monofilament and the newer polyglycol sutures are more effective than multifilamented sutures and plain catgut in preventing infection in the closure of contaminated wounds.[7]

Hemostasis, seroma, "dead spaces." When blood or serum is allowed to accumulate within wounds, hematomas, seromas, or "dead spaces" result. These accumulations separate wound walls, delay healing, and provide a favorable medium for bacterial growth. Optimal clamping or ligation of blood vessels can decrease the risk of infection by increasing the completeness of hemostasis. In some situations, surgical drains facilitate postoperative drainage of blood, serum, or other secretions.

Time, type, and thoroughness of treatment. If definitive treatment of wounds is delayed more than four to six hours after injury, the chance of wound infection is increased significantly. All devitalized tissue and foreign bodies should be excised and removed as early as possible. The development of more nonviable tissue and a decrease in local resistance of tissues to infection can result from inadequate debridement per se or from primary closure of incompletely debrided wounds.

Multiplicity of severe wounds. In the patient with many severe injuries, one or more wounds may by necessity be inadequately debrided, that is, overall treatment of the patient with severe shock, hemorrhage, or associated wounds of the chest and head may delay the local treatment of other wounds.

Local and general immune responses. Abnormalities of the body's antimicrobial immune mechanisms increase the likelihood of sepsis and usually have one of three manifestations: reduction of the inflammatory response, interference with leukocyte function, or interference with opsonins (humoral immunity). The inflammatory response can be reduced by any factor that prevents delivery of phagocytes to critical areas; uremia, radiation injury, severe nutritional deficiencies, and use of vasopressors, adrenocortical steroids, opiates, ethanol, and large amounts of salicylates are other contributing factors. Leukocyte function is impeded by many factors, including severe burns, nutritional deficiencies, use of adrenocortical steroids, and continued stress.

Hyperimmune gamma globulin has proved beneficial as an adjunctive measure in septicemia and burn-wound sepsis caused by *Pseudomonas aeruginosa*. More specifically, however, vaccination with a heptavalent Pseudomonas vaccine reduced deaths from Pseudomonas sepsis 80% in patients who had survived initial resuscitation after large burn injuries; the infection had developed despite vigorous systemic and topical antimicrobial therapy with effective agents.[9]

Associated Diseases and Other Contributing Factors in Wound Infection

Associated diseases. Patients with diabetes, uremia, or cirrhosis have a higher rate of surgical wound infection than that of the general population. According to the five-university Ultraviolet Collaborative Study,[10] the wound-infection rate among 356 diabetic patients was 10.4%, as compared with an overall wound infection rate of 7.4% among the 15,613 patients studied.

Age. In the same study, patients between 50 and 80 years old had increased wound infections: 9.8%, as compared with an incidence of 7.4% for all age-groups.[10] This finding is significant because of the number of surgical operations among elderly patients for malignant tumors and for acquired cardiovascular diseases.

Obesity. Experienced surgeons have long maintained that severe obesity predisposes patients to wound infections, a belief confirmed by an 18.1% wound infection rate among 166 severely obese patients, as compared with the overall 7.4% wound infection rate for the 15,613 patients studied.[10] (Adjustment for the greater duration of surgical procedures in obese patients reduced the incidence of wound infection, but only to 16.5%.)

Duration of operation. At all five hospitals participating in the Ultraviolet Collaborative Study, the rate of wound infection increased progressively with the duration of operation, rising from 3.6% for operations lasting less than 30 minutes to 17.6% for those lasting six hours or longer.[10] (The overall rate of wound infection was 7.4%.)

Malnutrition. Among 67 severely malnourished postsurgical patients the rate of wound infection was 22.4%.[10] Although many of the patients were old, had undergone long operations, or had had operations more likely to be associated with greater contamination than the average patient, malnourishment was presumed to have contributed to this increase from the overall rate of wound infection.[10]

Duration of preoperative hospitalization. Studies at the University of Cincinnati Medical Center showed that the incidence of postoperative wound infection was three times greater in patients hospitalized 14 days or more before surgery than in those hospitalized only one to three days before surgery,[11] a finding confirmed by Hare in London and by others.

Remote infection. In the Ultraviolet Collaborative Study, the wound infection rate was 18.4% among patients who harbored infection remote from the operative incision, as compared with a rate of 6.7% among patients who lacked such remote infection.[10]

Steroid therapy. Among 119 patients who had been given steroid therapy, the rate of wound infection was 16.0%, as compared with an overall infection rate of 7.4% for all 15,613 patients. Although the 16.0% rate was probably influenced by the fact that many of these patients were old, had undergone long operations, or had been hospitalized longer preoperatively than the average patient, steroid therapy was presumed to be a contributing factor. Steroid therapy apparently may weaken host defenses by depressing antibody formation, altering vascular reactivity, diminishing phagocytic capacity, or suppressing vascular neogenesis and fibrogenesis.

Therapy of neoplasia. The use of anticancer drugs, immunosuppressive agents, or extensive irradiation in patients with cancer may cause leukopenia, thereby increasing the rate of wound infection.

Iatrogenic infections. Prolonged intravenous therapy (72 hours or longer) is very likely to lead to thrombophlebitis or active cellulitis, accompanied by discomfort, fever, and increased morbidity. A relatively new syndrome, designated "third-day fever," is attributed to contamination of an intravenous solution or catheter; a Gram-negative (Klebsiella) septicemia—characterized by chills, high fever, septic shock, and oliguria—develops three days after surgery in trauma and other high-risk patients.[12,13]

Indwelling urinary catheters, urinary tract instrumentation, and various diagnostic procedures play important roles as determinants of iatrogenic infections. In a recent study at the Cincinnati General Hospital, 53% of the invasive Gram-negative infections with septicemia originated in the urinary tract.

Tracheostomy may introduce life-threatening pulmonary infections caused by virulent bacteria found in the hospital environment, particularly *Staphylococcus aureus* and *Pseudomonas sp.*

Certain anesthetic procedures may contribute to iatrogenic infections. In most patients, even when asymptomatic, virulent or potentially pathogenic organisms can be found on the surface of the mucous membrane of the respiratory tract. If the local resistance of these tissues is depressed or if the mucous membrane is broken by instrumentation, opportunistic microorganisms can initiate respiratory infections.[3] The opportunity for infection by bacteria present in the respiratory tract has been increased in recent years by extension of surgical operations to some old or debilitated patients who require prolonged, complicated anesthesia. Infection of the central nervous system (e.g., meningitis) occasionally results from spinal or epidural anesthesia.[14]

Microbial Etiologic Factors

Infections have their bacterial etiologic source in one of three reservoirs: community-based or home-based infections, operating room-based infections, and hospital-based (nosocomial) infections.

Community-based or home-based infections are already present when the patients are admitted to the hospital. These infections account for 30% to 40% of surgical infections and include acute appendicitis, acute cholecystitis, acute diverticulitis with perforation and peritonitis, bite wounds, and foreign bodies.

Operating room-based infections are chiefly surgical wound infections that occur postoperatively and are directly linked to surgical procedures.

Hospital-based (nosocomial) infections may occur preoperatively or postoperatively. They usually follow a diagnostic or therapeutic procedure (e.g., arteriography, catheterization or instrumentation of the lower urinary tract, tracheostomy, and prolonged intravenous therapy, as mentioned above) that permits the physiologic interior of the body to be invaded by bacteria resident in the hospital, most often antibiotic-resistant and virulent microorganisms. Table II lists the organisms—bacteria, fungi, and viruses—responsible for surgical infections, including individual species of

TABLE II. MICROORGANISMS RESPONSIBLE FOR SURGICAL INFECTIONS

I. Bacterial infections
  A. Aerobic bacteria
    1. Gram-positive coccus
      Staphylococcus
      Streptococcus
      Streptococcus pneumoniae (pneumococcus)
    2. Gram-negative coccus
      Neisseria catarrhalis
      Neisseria gonorrhoeae
    3. Gram-negative bacillus
      Escherichia coli
      Enterobacter aerogenes (Aerobacter aerogenes)
      Enterobacter cloacae
      Klebsiella
      Pseudomonas aeruginosa
      Proteus
      Proteus inconstans (Providencia stuartii)
      Serratia marcescens
      Citrobacter
      Alcaligenes faecalis
      Salmonella
      Hemophilus influenzae
    4. Gram-positive bacillus
      Bacillus anthracis
      Bacillus sp.
      Corynebacterium
      Diphtheroids
      Mycobacterium tuberculosis
      Mycobacterium marinum (Mycobacterium balnei)
  B. Microaerophilic bacteria
    1. Gram-positive coccus
      Streptococcus
        Hemolytic
        Nonhemolytic
  C. Anaerobic bacteria
    1. Gram-positive coccus
      Peptococcus
      Peptostreptococcus

particular clinical significance. The microbiological pattern of infection in trauma patients has changed in recent years. For decades the species of bacteria of greatest importance in wound infections were aerobic Gram-positive cocci (e.g., Staphylococcus, Streptococcus, and pneumococcus). The last two decades have shown the following changes:

1) An increasing incidence of Gram-negative infections, accounting for about two thirds of wound infections. The increase seems related to widespread use of antibiotics, to iatrogenic factors, and to the extension of new and complex diagnostic and surgical procedures to high-risk patients. The bacteria most often involved are *Escherichia coli, Enterobacter*

TABLE II continued

2. Gram-positive bacillus
   Clostridium perfringens
   Clostridium novyi
   Clostridium septicum
   Clostridium histolyticum
   Clostridium tetani
3. Gram-negative bacillus
   Bacteroides sp.
   Bacteroides fragilis
   Bacteroides melaninogenicus
   Fusobacterium

D. Mixed infections
   Aerobic and anaerobic microorganisms
   Gram-positive and Gram-negative microorganisms
   Synergistic microorganisms

II. Nonbacterial infections

A. Fungi
   Candidiasis *(Candida albicans)*
   Blastomycosis *(Blastomyces dermatitidis)*
   Coccidioidomycosis *(Coccidioides immitis)*
   Histoplasmosis *(Histoplasma capsulatum)*
   Sporotrichosis *(Sporotrichum schenkii)*
   Phycomycosis *(Mucor sp.)*
   Aspergillosis *(Aspergillus niger)*
   Fusarium sp.
   Actinomycosis *(Actinomyces israelii, Arachnia propionica)* } no longer considered fungi
   Nocardiosis *(Nocardia asteroides)*

B. Viruses
   Herpesvirus
   Poxvirus (vaccinia)
   Varicella (herpes zoster virus)
   Cytomegaloviruses
   Mumps virus (parotitis and pancreatitis)
   Poliovirus
   Hepatitis virus (infectious and serum)
   Rabies virus

aerogenes, Proteus, *P. aeruginosa*, and Serratia.[13,15]

2) Development of superimposed or secondary infections during antibiotic therapy, such as *Serratia marcescens* septicemia during therapy with penicillin (more than 20 million units/day) or cephalothin.[15]

3) An increasing incidence of Gram-negative infections by bacteria of low virulence (e.g., *S. marcescens*).

4) An increasing incidence of mixed bacterial infections of wounds that involve synergistic bacterial action.

5) An increasing incidence of infections by *Candida albicans*, espe-

cially among patients with severe injuries or those receiving immunosuppressive drugs.

6) In an increasing number of infections—especially thrombophlebitis, wound abscesses, brain abscesses, tubo-ovarian abscesses, abdominal abscesses, and empyema—atypical bacterial forms (including "L" forms) are found. The etiologic significance of these forms remains unclear.

7) The increased significance of Gram-negative anaerobic infections, caused principally by *Bacteroides sp.*

8) During the past two years a new phage type (83A,85) of Staphylococcus has emerged spontaneously and increased among staphylococcal isolates at the Department of Surgery of the University of Cincinnati. This phage type of Staphylococcus, which appears to have pathogenic potential, is highly resistant to the synthetic penicillins and most other antibiotics generally used for staphylococcal control. Judging from previous studies of other spontaneously emerging phage types of Staphylococcus during the past 20 years, we can anticipate that infections by this new phage type will continue for at least three or four more years before it spontaneously disappears.

Surgical Techniques to Prevent or Control Infection

The mere presence of virulent bacteria in a wound does not make infection of that wound a certainty. Infection may be considered the unfavorable result of this equation:

$$\frac{\text{Dose of bacteria} \times \text{Virulence}}{\text{Resistance}} = \text{Probability of infection.}$$

The chance of infection is minimized when the dose of bacteria in any wound is reduced, virulent bacteria in the environment are minimized, and the patient's resistance is kept at a maximum.

Preoperatively, removal of skin hair, degerming the skin by washing and application of antiseptics, and proper surgical draping are significant measures to minimize wound infection, aside from efforts to alter any of the determinants of wound infection cited earlier.

We recommend that shaving of the patient's skin be done not more than two hours before operation, that it is best done "wet" with detergent or soap and disposable razors, and that injury or irritation of the skin should be avoided.

One cannot sterilize the skin of the operative site or the surgeon without damaging or destroying it. At best, the skin can be disinfected by methods that usually leave some bacteria in the disinfected area.[17] Various aseptic techniques are modified according to circumstances; for example, an open, dirty, and contaminated wound may require a longer skin scrub than usual, as well as irrigation with copious amounts of saline solution. Antiseptics and detergents, because locally irritating, should be kept out of open wounds. Wound towels, adhesive skin drapes, and moist laparotomy pads are also bacterial barriers.

The rate of wound infection and the course of such infections can be affected by appropriate use of isolation techniques. Five well-defined categories of isolation can be employed for surgical patients: strict isolation, respiratory isolation, wound and skin precautions, enteric precautions, and protective isolation. Different diseases require different categories of isolation. It is taken for granted that aseptic techniques are used in the operating room and when changing and disposing of wound dressings postoperatively.

General Principles of Antibiotic Use

Sensitivity. Theoretically, laboratory identification of microbes and determination of their susceptibility to specific antimicrobial agents should be the basis of effective drug therapy. In practice, this may not be so. For some infections (e.g., those caused by Group A beta-hemolytic streptococci), there may often be no need to test the organisms for sensitivity once identified. In some other cases it may be more important to determine the drug sensitivity of an organism than to identify it. In rapidly developing serious infections, drug therapy may have to be started before the organisms can be cultured; the drugs chosen are those known to be effective against the organisms most often associated with the particular clinical constellation. Very useful and immediate information may be obtained from microscopic examination of stained direct smears.

If the response to drug therapy is not satisfactory, further tests may be needed to determine whether a new organism is present, whether the initial drug susceptibility of the original organism has changed, or whether drug-insensitive organisms, present initially in small numbers, have become the predominant flora. Other possibilities include undrained abscesses or metastatic infections.

Contact. To be effective, the antimicrobial drug—whether systemic or topical—must make contact with the organism at an appropriate stage in its metabolic cycle. When the drug is used systemically, blood flow to the area of infection must be sufficient to yield an effective concentration of the antimicrobial agent at the desired site of activity. When applied topically, the agent must reach every part of the lesion.

Some lesions (e.g., pyogenic abscesses) are not penetrated readily by the drug because it is blocked by dense avascular tissue or by necrotic tissue; the latter may interfere with the drug's activity and with the mechanisms of host immunity.

Adverse effects. The antimicrobial drug should be relatively free from adverse side effects. The clinician should be familiar with the possible untoward effects of the drug prescribed, monitor the patient for the appearance of these effects, and be prepared to cope with them. Possible manifestations of adverse effects range from fever, skin rash, and gastrointestinal disturbances through renal tubular necrosis, blood dyscrasias, neurotoxicity, and anaphylactoid shock.

Interference. No substance at the site of microbial activity should interfere with the action of the antimicrobial agent. Specific enzymic inhibitors (e.g., penicillinase or cephalosporinase), incompatible drugs, or the presence of a coagulum in an open wound all can limit the effectiveness of an antibiotic.

Active host defenses. The defense mechanisms of the host against infection should be active. Many antibiotics are bacteriostatic rather than bactericidal, and when bacteriostatic drugs are used, ultimate resolution of the infection is achieved by the body's natural defenses.

Other principles involved in the proper use of antibiotics are early and accurate diagnosis of infection, prompt administration of the most effective agents in sufficient dosage, and early search for responsible factors when initial antibiotic therapy does not yield the expected response.

Special Considerations for Use of Antibiotics in Surgical Wound Infections

Effective treatment of wound infections requires the presence of an adequate concentration of an appropriate antibiotic at the time of contamination or shortly thereafter. An objective of treatment of wounds that are already inflamed and possibly containing pus is the prevention of intracavitary spread of distant dissemination and the prevention of infection in associated fresh operative wounds or previously unsoiled tissue planes.

Because one of the factors that determine the probability of infection in a surgical wound is the number of bacteria in the wound when the operation is finished,[18] it is possible to estimate the degree of contamination clinically and to classify the wound in one of four categories: clean, clean-contaminated, contaminated, or dirty and infected. In the Ultraviolet Collaborative Study, the average incidence of infection in these four wound categories was 5.0%, 10.8%, 16.3%, and 28.5%, respectively.[10] Another prospective study of 23,649 surgical wounds yielded comparative incidences of 1.8%, 8.9%, 21.5%, and 38.0%.[19] These wound categories are reasonable predictors of the probability of wound infection.

Special Considerations for Use of Antibiotics in Wounds Caused by Trauma

Although many traumatic wounds are contaminated or dirty and infected, indiscriminate use of antimicrobial agents in a patient with wounds is to be avoided. It should always be kept in mind that the *sine qua non* of wound management is sound and careful surgery and that antimicrobial agents are adjunctive when an infection is present. It is to be emphasized that antibacterial therapy should be started in the surgery of trauma as soon after injury as possible and before an infection becomes fully established. The administration should be continued intraoperatively and postoperatively if adverse effects are to be minimized.

In certain types of wounds caused by trauma, antibiotic treatment may be started on a presumptive diagnosis of infection. These conditions may occur when:

1) The wound enters a joint space or is associated with an open fracture.

2) There is heavy contamination.

3) Adequate debridement is not feasible or desirable (as in injuries to the tendons or fascial spaces of the hand).

4) Debridement is delayed.

5) The patient has been burned.

6) The gastrointestinal tract is involved.

7) The injuries are prone to the development of clostridial infection. The likelihood of clostridial infection is greatest when extensive devitalization of skeletal muscle is present, especially in limbs with arterial insufficiency, in wounds with gross contamination and retained foreign bodies, and in wounds treated inadequately or belatedly.

Antibiotic treatment should be initiated preoperatively and continued intraoperatively and postoperatively. After surgical debridement of these wounds, either without closure or with delayed closure, penicillin G, tetracycline, a tetracycline derivative (such as doxycycline), or chloramphenicol is given.

Certain other special situations, both traumatic and nontraumatic, in which the early use of antibiotics is warranted are included in the following:

Infection-prone patients. Some patients are known to be more infection-prone than the average individual. These include known carriers of pathogenic staphylococci in their upper respiratory tracts and those with active infections elsewhere in the body. Prolonged antibiotic therapy may place individuals at increased risk to superinfections by opportunistic bacteria. This also applies to patients with known or suspected tuberculosis, patients with rheumatic valvular disease, or patients with valvular implants.

Urinary tract infection. Early use of systemic antibiotics is recommended when instrumentation or an incision is required to enter the urinary tract in the presence of infection, contaminated urine, or obstructive uropathy. In instances of prolonged urinary catheterization, a closed drainage system is mandatory. The topical application of an antibiotic ointment to the urethral meatus is also recommended.

Infections from intravenous infusion. Microorganisms introduced through continuous intravenous systems may be an important source of nosocomial infections. Most of these bacteria are Gram-negative aerobes, and the infections result from intravenous infusion of contaminated fluids. Areas of cellulitis and thrombophlebitis in the vicinity of the venous puncture usually can be seen. Preventive measures include careful cleansing and application of antiseptic solutions before venipuncture and aseptic precautions during the duration of the infusion. Change of the intravenous setup is recommended in less than 72 hours in most instances. If evidence of cellulitis and thrombophlebitis develops, the intravenous catheter should be removed immediately, and antibiotic therapy appropriate for the suspected organism instituted. The organism should be identified, and its susceptibility should be determined by bacteriologic culture and testing.

Summary

Experience has shown that the prevention and control of infections in trauma patients is largely a matter of attitude. The surgeon not only must

be mindful that infection may develop as a complication but must know the important determinants of infection and possess the skills to apply the principles and techniques to avoid the effects of these determinants.

Recognition of the primary importance of established principles of surgical wound care and the application of intelligent therapy as adjunctive measures will do much to prevent and to control post-trauma infections.

Discussion

QUESTION: Dr. Altemeier, what antibiotics would you use in a patient with a gunshot wound in the abdomen who is in shock, is rushed to surgery, and in whom an infection is not fully established?

DR. ALTEMEIER: In Cincinnati, where the police department provides transportation for such victims, most patients reach the hospital within half an hour from the time they were shot. Because a gunshot wound in the abdomen often produces infection from the gastrointestinal tract, broad-spectrum antibiotic coverage is almost always indicated. We therefore combine a tetracycline with another agent that has increased effectiveness against Gram-positive organisms.

Since 1958, when we started this regimen in penetrating wounds to the abdomen, our mortality rate has remained between 8% and 11%, and our incidence of infection in these patients has ranged between 4% and 6%. However, it is absolutely essential to start antibiotic therapy preoperatively and before an infection becomes fully established. A delay in the administration of antibiotics of even four or six hours will not permit this combination or any combination of antibiotic agents that we have tried to be effective, and the incidence of infection will triple within a period of six to eight hours. When administration of antibiotics is delayed until after the operation has been completed, the incidence of infection may reach as high as 38% to 40%. So, the earlier antibiotics are started, the better.

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